

# Instrumentation and Controls Division Overview

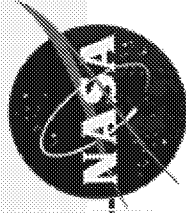
<http://www.grc.nasa.gov/WWW/ictd/>

Dr. Mary V. Zeller

Phone: 216.433.2061

E-mail: [mary.zeller@grc.nasa.gov](mailto:mary.zeller@grc.nasa.gov)

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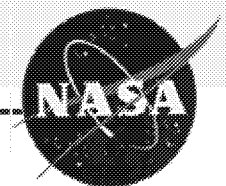
at Lewis Field

# Our Mission

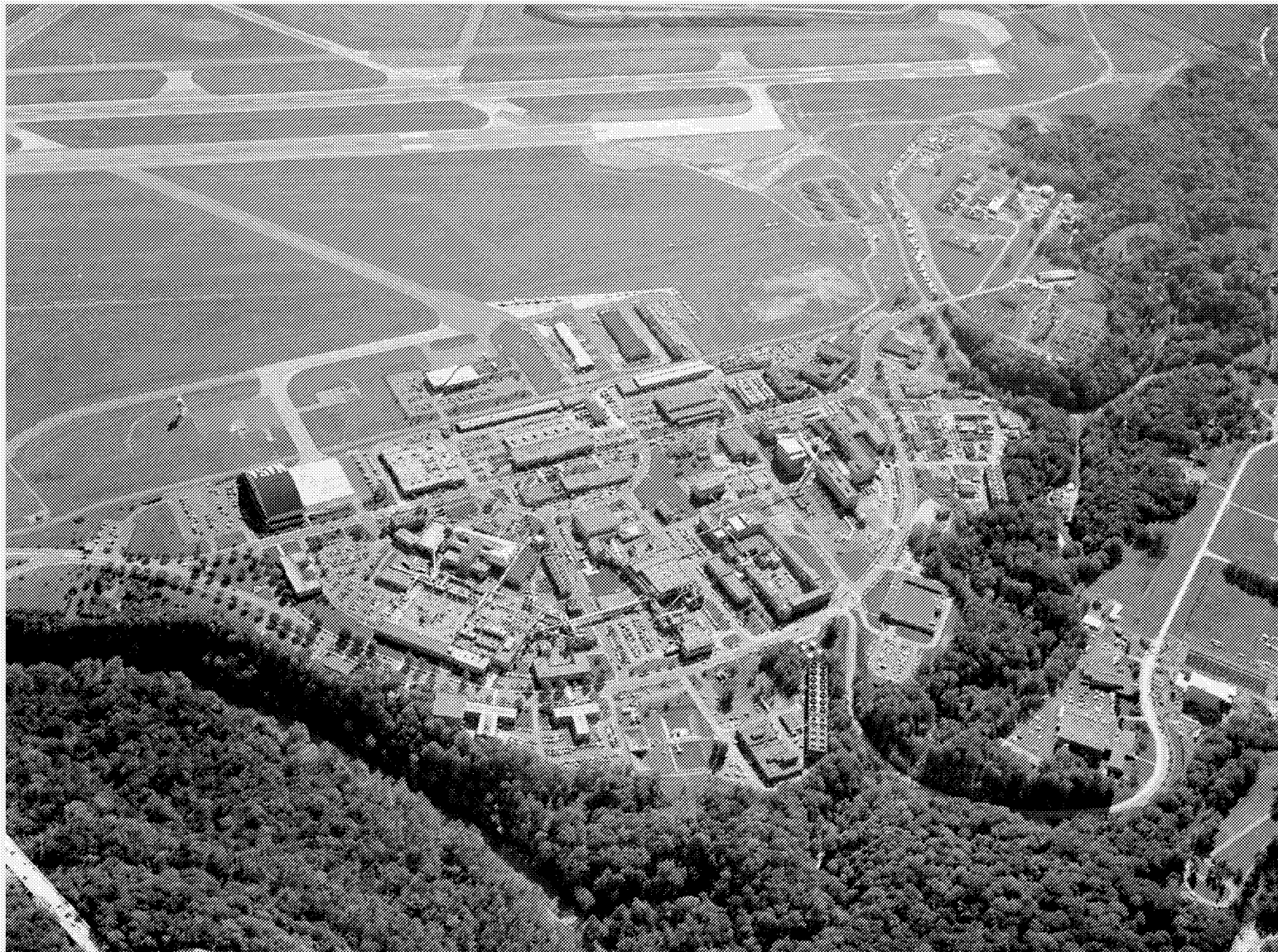
The **Instrumentation and Controls** Division is responsible for planning, conducting and directing basic and applied research on advanced instrumentation and controls technologies for **aerospace propulsion and power** applications. The Division's advanced research in **harsh environment sensors, high temperature high power electronics, MEMS, nanotechnology, high data rate optical instrumentation, active and intelligent controls, and health monitoring and management** will enable self-feeling, self-thinking, self-reconfiguring and self-healing Aerospace Propulsion Systems. These research areas address Agency challenges to deliver aerospace systems with reduced size and weight, and increased functionality and intelligence for future NASA missions in advanced aeronautics, economical space transportation, and pioneering space exploration. The Division also actively supports educational and technology transfer activities aimed at benefiting all humankind.

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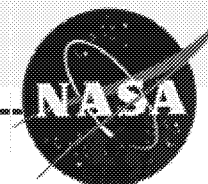
9/13/02



Welcome to John H. Glenn Research Center at Lewis Field

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# Organization

Director - D. Campbell  
Deputy Director – J. Earls  
Deputy Director for Operations - J. Earls\*  
Assistant Deputy Director for Policy - J. Gaff  
Chief Scientist - M. Goldstein

Office of the  
Chief Council  
B. Sikora

Office of Safety &  
Assurance Tech.  
B. Wessel

Aeropropulsion  
Research Office  
G. Seng

Plans and  
Programs Office  
O. Gonzalez-  
Sanabria

Office of Equal  
Opportunity  
R. Romero

Office of Chief  
Financial Officer  
B. Fails

Office of Human  
Resources  
J. Gaff \*

Office of  
Acquisition  
J. Earls\*

Aeronautics  
Directorate  
A. Sehra

Engineering and  
Technical Services  
R. Furnas

External  
Programs  
J. Hairston

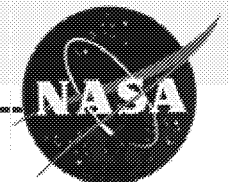
Research and  
Technology  
W. Whitlow

Space  
Directorate  
G. Barna

\* Acting

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5000

**Research & Technology Directorate****Dr. Woodrow Whitlow, Jr., Director****Dr. Lawrence J. Bober, Deputy***Marti Trujillo/Barbara Bartos, Secretaries**Susan M. Hennie, Executive Officer**Phone: (216) 433-3193**FAX: (216) 433-8581**Email: woodrow.whitlow@grc.nasa.gov*

5010

**Office of University Programs****Francis J. Montegani****University Affairs Officer***Toni B. Rusnak**Research Program Assistant*

5100

**Materials Division***Hugh R. Gray  
Chief*

- 5120/Advanced Metallics Branch
- 5130/Ceramics Branch
- 5150/Polymers Branch
- 5160/Environmental Durability Branch

5400

**Power & On-Board  
Propulsion Technology  
Division***Valerie J. Lyons  
Chief*

- 5410 Photovoltaic & Space Environment Branch
- 5420/Electrochemistry Branch
- 5430/On-Board Propulsion Branch
- 5450/Electrical Systems Development Branch
- 5480/Electrophysics Branch
- 5490/Thermo-Mechanical Systems Branch

5500

**Instrumentation &  
Controls Division***Jih-Fen Lei  
Chief*

- 5510/Sensors & Electronics Technology Branch
- 5520/Optical Instrumentation Technology Branch
- 5530/Controls & Dynamics Technology Branch

5600

**Communications  
Technology  
Division***W. Daniel Williams  
Chief*

- 5610/Satellite Networks & Architectures Branch
- 5620/Electron Device Technology Branch
- 5640/Applied RF Technology Branch
- 5650/Digital Communication Technology Branch

5800

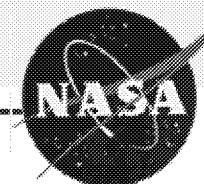
**Turbomachinery  
& Propulsion  
Systems Division***D.R. Reddy  
Chief*

- 5810/Compressor Branch
- 5820/Turbine Branch
- 5830/Combustion Branch
- 5840/Icing Branch
- 5850/Inlet Branch
- 5860/Nozzle Branch
- 5870/Propellant Systems Technology Branch
- 5880/Engine Systems Technology Branch

5900

**Structures &  
Acoustics Division***L. James Kiraly  
Chief*

- 5920/Life Prediction Branch
- 5930/Structural Mechanics & Dynamics Branch
- 5940/Acoustics Branch
- 5950/Mechanical Components Branch
- 5960/Tribology & Surface Science Branch

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5500 MS 77-1  
**INSTRUMENTATION & CONTROLS DIVISION**

*Dr. Jih-Fen Lei, Chief*  
*Patricia A. Lewis, Secretary*

Phone: (216) 433-6328 FAX: (216) 433-8990  
Email: [jih-fen.lei@grc.nasa.gov](mailto:jih-fen.lei@grc.nasa.gov)

5510  
**Sensors & Electronics  
Technology Branch**

*Dr. Lawrence G. Matus*  
*Chief*

Phone: (216) 433-3650  
FAX: (216) 433-8990  
Email: [lawrence.g.matus@grc.nasa.gov](mailto:lawrence.g.matus@grc.nasa.gov)

- High Temperature, High Power Electronics
- Chemical Sensors for Emission, Leak Detection, and Safety
- Physical Sensors for Harsh Environments
- MEMS & SiC Nanotube

5520  
**Optical Instrumentation  
Technology Branch**

*Dr. Carolyn R. Mercer*  
*Chief*

Phone: (216) 433-3411  
FAX: (216) 433-8990  
Email: [carolyn.mercer@grc.nasa.gov](mailto:carolyn.mercer@grc.nasa.gov)

- Optical Ground Test Instrumentation
- Optical Sensors and Systems for Flight
- Electro-Optic Circuitry for Mobile Sensor Platforms

5530  
**Controls & Dynamics  
Technology Branch**

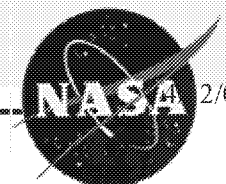
*Dr. Sanjay Garg*  
*Chief*

Phone: (216) 433-2685  
FAX: (216) 433-8990  
Email: [sanjay.garg@grc.nasa.gov](mailto:sanjay.garg@grc.nasa.gov)

- Advanced Propulsion Control Concept
- Dynamics Theory and Modeling
- Active and Intelligent Controls
- Health Management
- Propulsion Control System Simulation, Implementation and Demonstration

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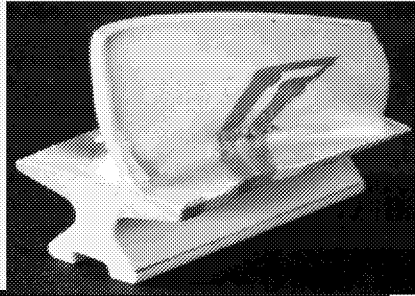


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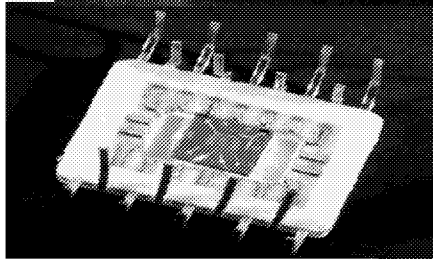
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# Instrumentation & Controls Division

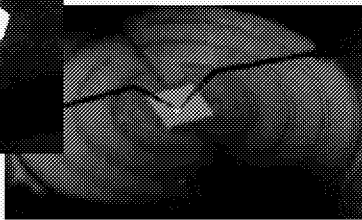
## Sensors & Electronics



High Temp  
Thin Film  
Sensor

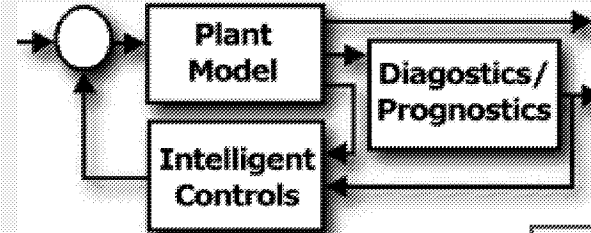


High Temp, High Power Electronics

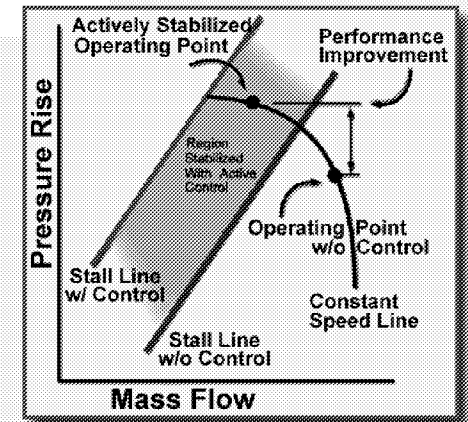


## Smart Systems for Air and Space

## Controls & Health Management

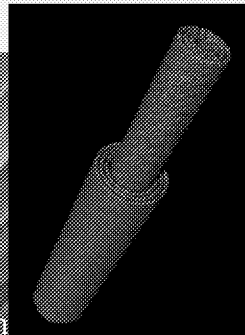
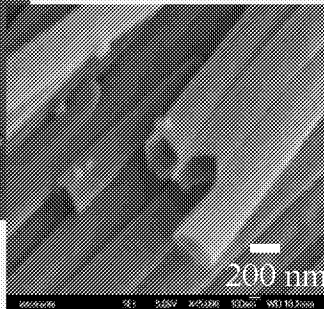
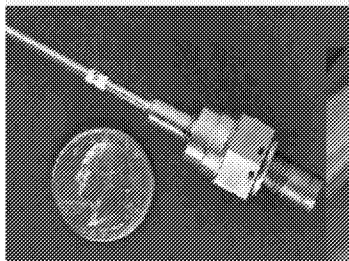


Intelligent Control &  
Health Management

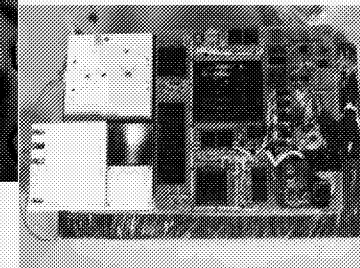
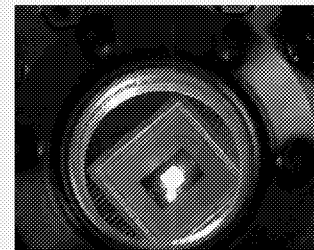


Active Control Technologies

## Nano/MicroElectroMechanical Systems

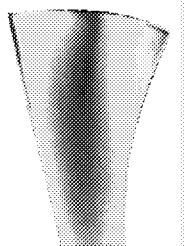


## Optical Instrumentation



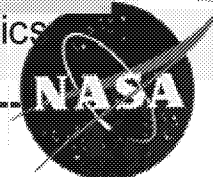
Electro-Optics

Facility  
Instrumentation



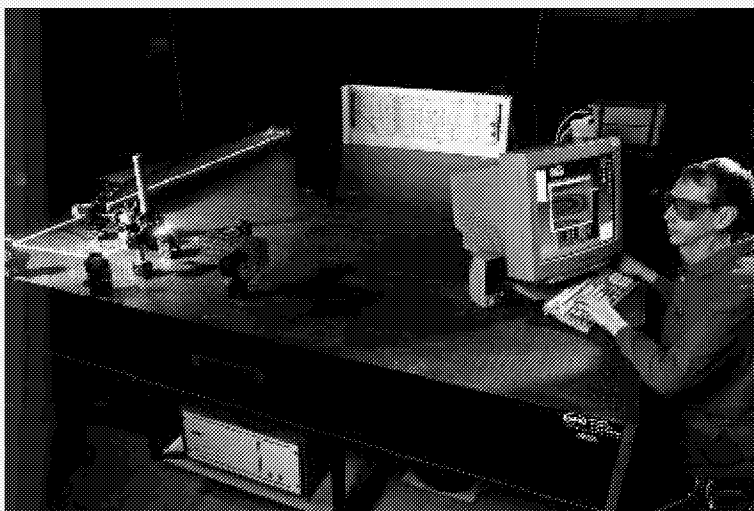
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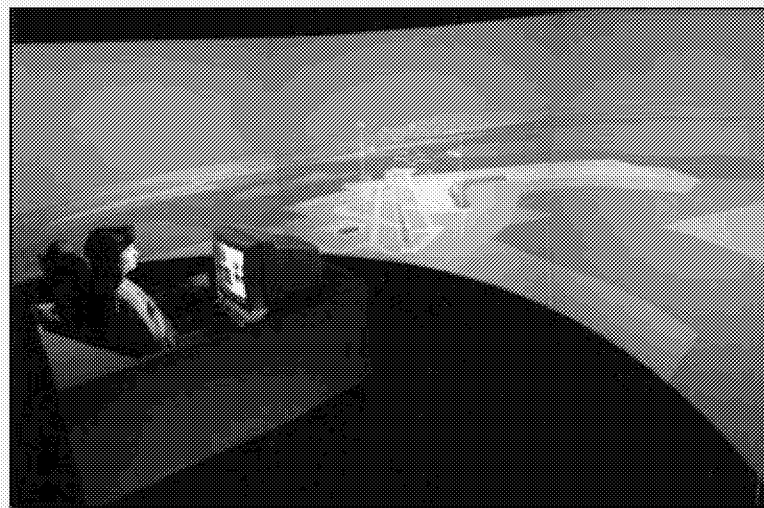


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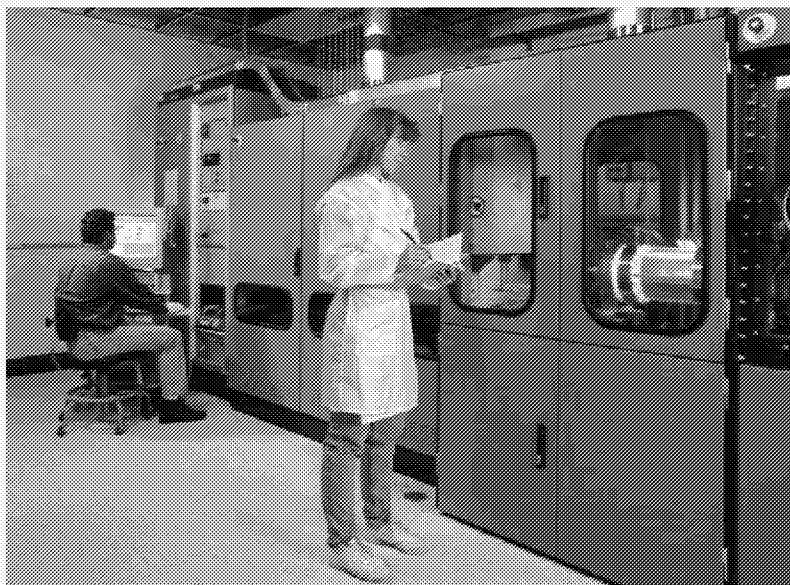
# Instrumentation and Controls Research Laboratories



Optical Instrumentation Research Lab



Real-Time Control Simulation Lab

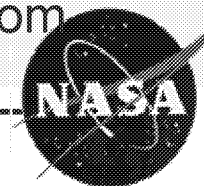


Electronics Crystal Growth Facility  
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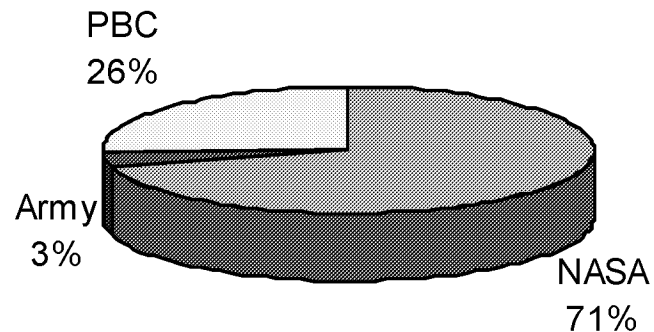


Class 100 Clean Room

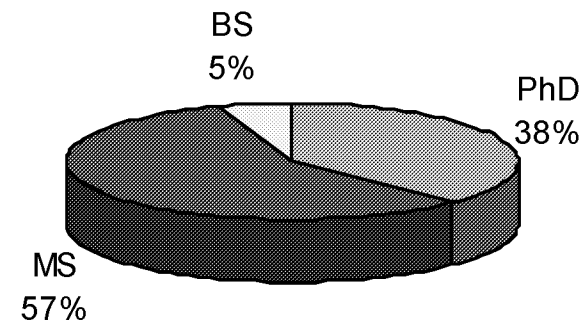
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# Instrumentation & Controls Division Workforce



## Technical Staff Education

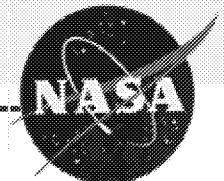


## Workforce Resource

- 45 NASA CS, 2 Army CS
- 17 on-site PBC
- Supported by 16 technician

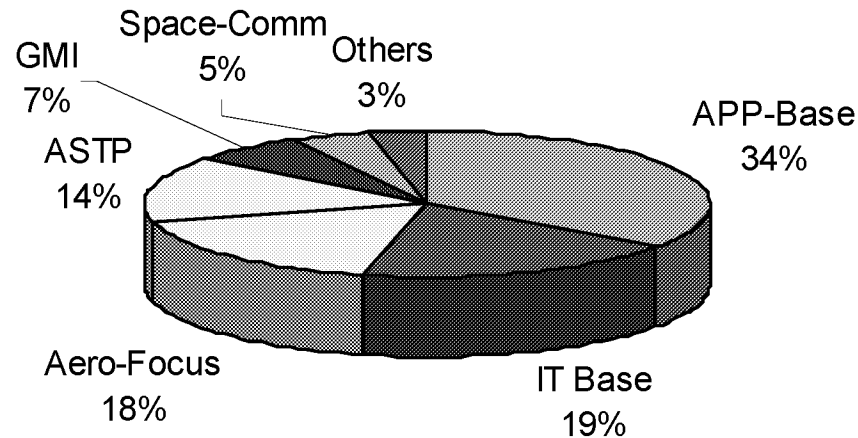
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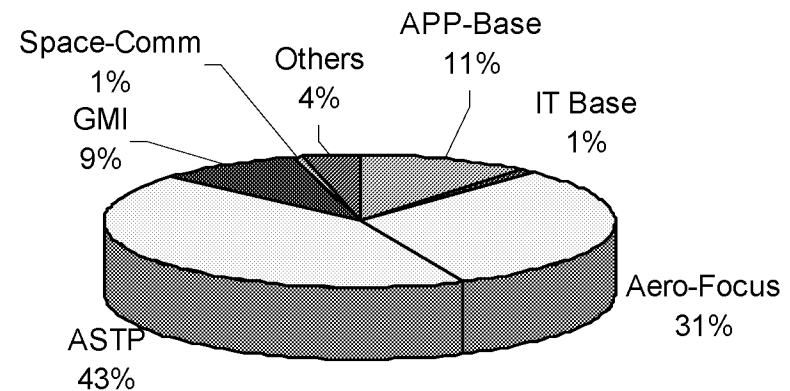


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# FY02 Workforce- Program Support Distribution



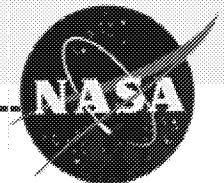
CS Workforce



PBC Workforce

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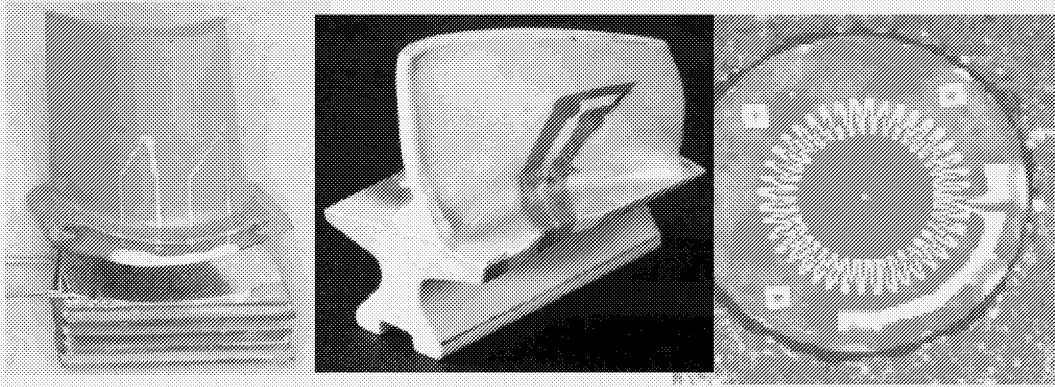
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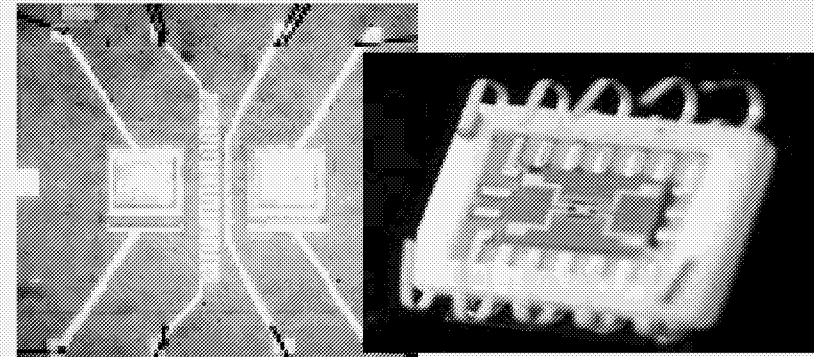
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# SENSORS AND ELECTRONICS TECHNOLOGY BRANCH

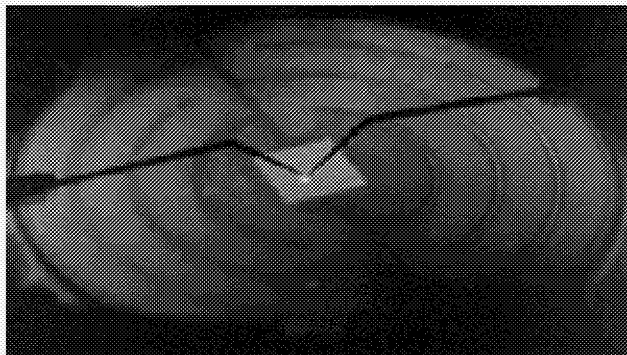
## *SCOPE OF WORK*



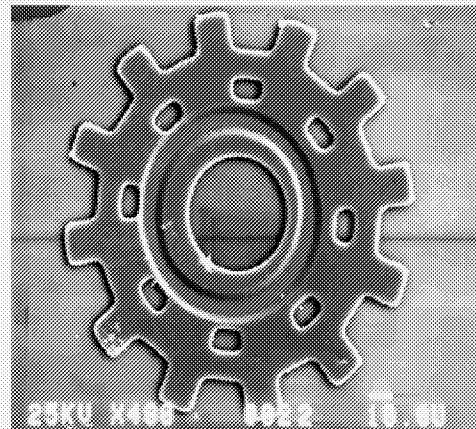
**PHYSICAL SENSORS (T, Strain, Heat Flux)**



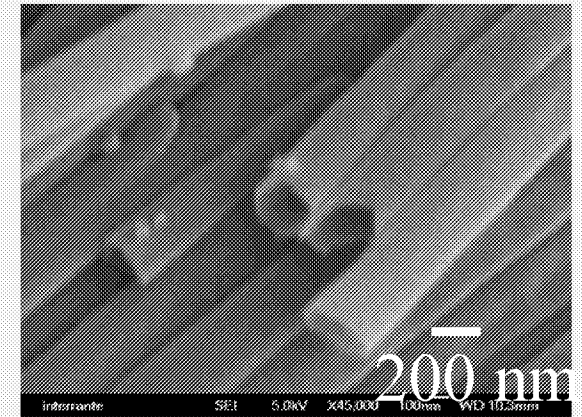
**CHEMICAL SENSORS**



**SILICON CARBIDE HIGH  
TEMP ELECTRONICS**



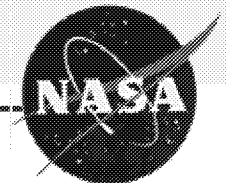
**MICRO-ELECTRO-  
MECHANICAL SYSTEMS**



**NANOTECHNOLOGY**

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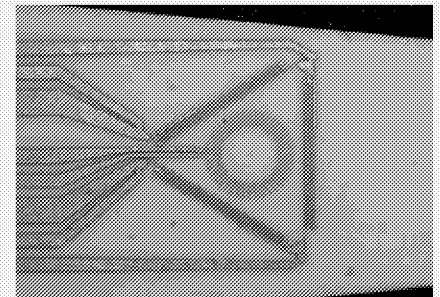
# Thin Film Physical Sensors for High Temperature Applications

- **Advantages for temperature, strain, heat flux, flow & pressure measurement:**

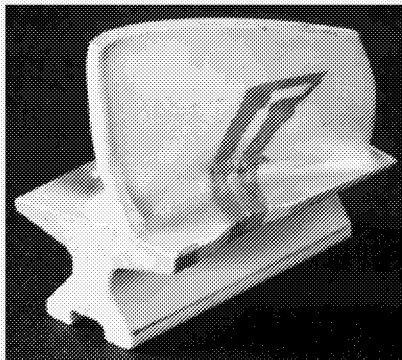
- ◆ Negligible mass & minimally intrusive (micron thick)
- ◆ Applicable to all materials including ceramic based materials
- ◆ Minimal structural disturbance
- ◆ Intimate sensor to substrate contact & accurate placement
- ◆ Multiple sensor fabrications, full field measurement
- ◆ High durability
- ◆ Capable for operation to very high temperatures ( $> 1000^{\circ}\text{C}$ )

- **Multifunctional smart sensors being developed**

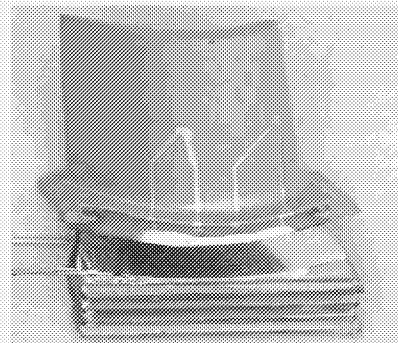
- **Next generation ceramic based sensor for  $T > 1200^{\circ}\text{C}$  being developed**



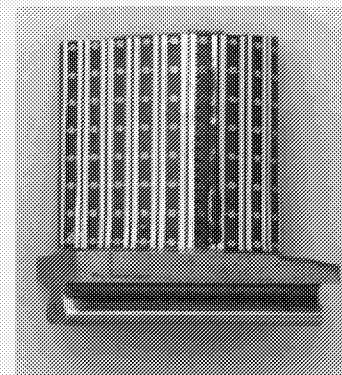
MULTIFUNCTIONAL SENSOR ARRAY



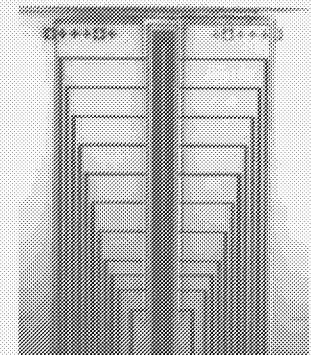
PdCr strain sensor  
to  $T=1000^{\circ}\text{C}$



Pt- Pt/Rh temperature  
sensor to  $T=1200^{\circ}\text{C}$



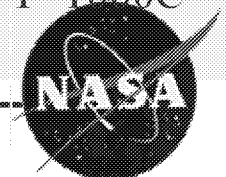
Heat Flux Sensor Array  
to  $T=1000^{\circ}\text{C}$



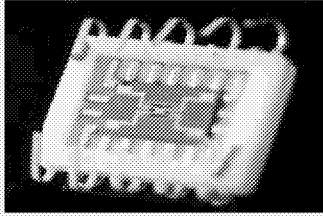
Flow sensor  
to  $T=1000^{\circ}\text{C}$

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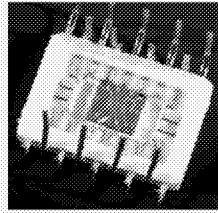
at Lewis Field



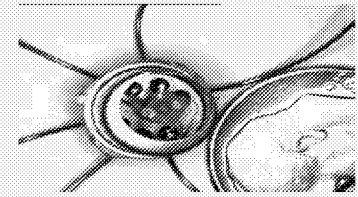
# HYDROGEN, OXYGEN, AND HYDROCARBON LEAK SENSOR TECHNOLOGY APPLICATIONS AND ACCEPTANCE CONTINUE TO EXPAND



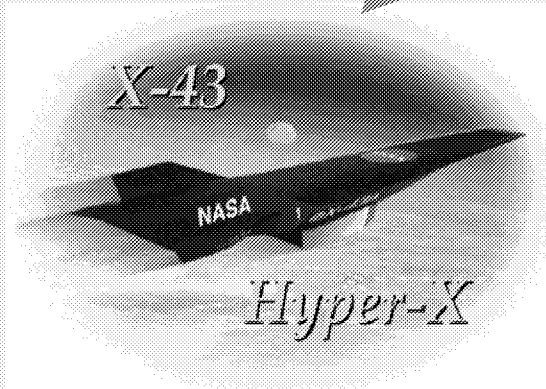
Oxygen Sensor



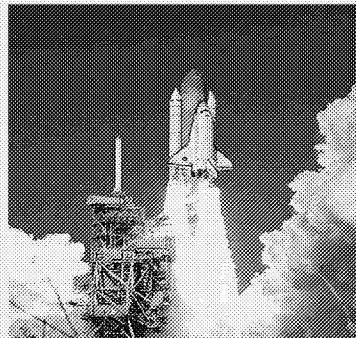
H2 Sensor



SiC Hydrocarbon Sensor

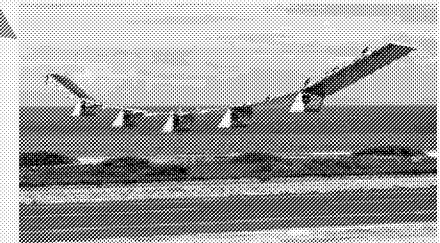


HYDROGEN SENSORS FLOWN ON TWO MISSIONS OF HYPER X.



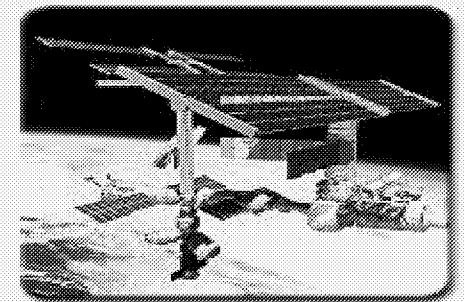
NASA KSC CONTINUES  
EVALUATION OF  
HYDROGEN SENSORS FOR  
GEN II PROGRAM

NASA JSC AGREES TO  
EVALUATION H2/O2  
TECHNOLOGY FOR AFT  
COMPARTMENT  
APPLICATIONS



HYDROGEN SENSOR  
CHOSEN FOR NASA HELIOS  
FUEL CELL SYSTEM

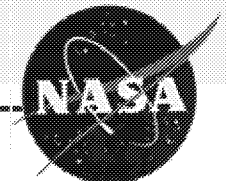
FORD MOTOR COMPANY JOINS GMI.  
INTEREST IN SiC GAS SENSOR TECHNOLOGY TO START  
BUT NOSE TECHNOLOGY AND HYDROGEN SENSORS  
ALSO OF INTEREST



HYDROGEN SENSOR SYSTEM CONTINUES  
DEVELOPMENT FOR ISS INCLUSION

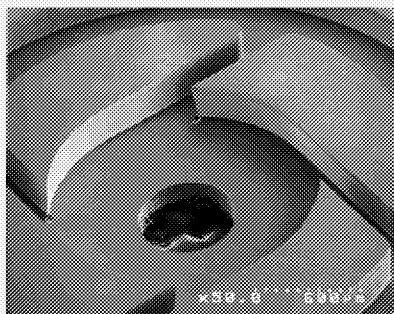
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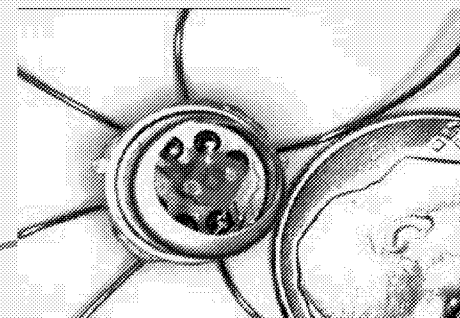
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# SiC-BASED MICROSYSTEM ACTIVITIES

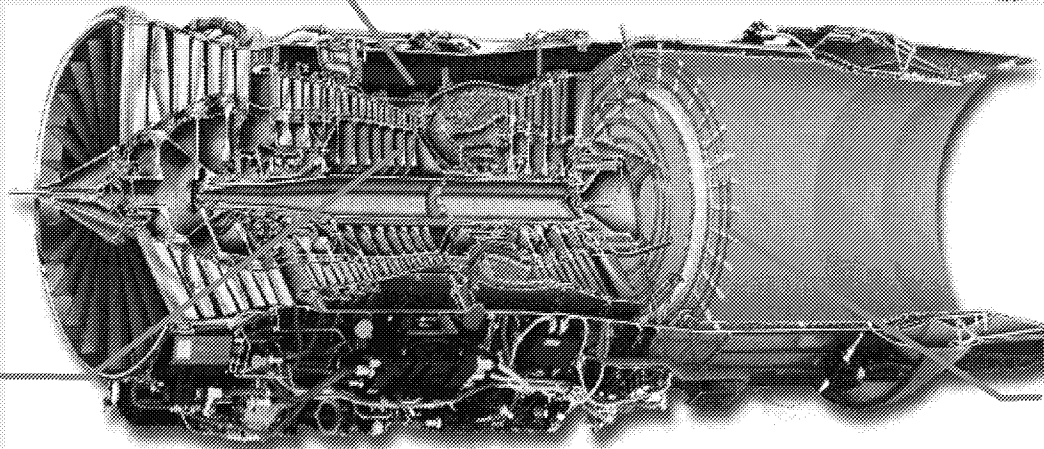
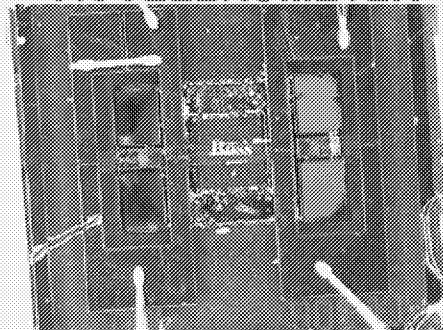


SiC-BASED  
ATOMIZERS

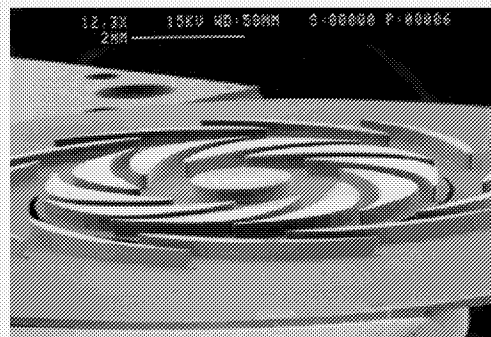
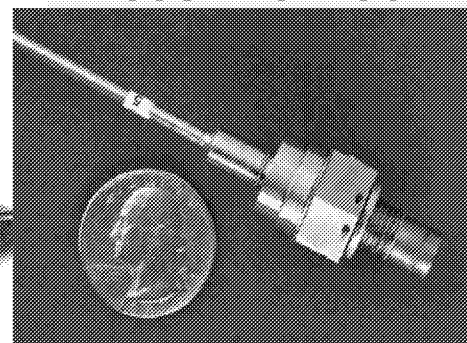
CHEMICAL SPECIES  
EMISSION SENSORS



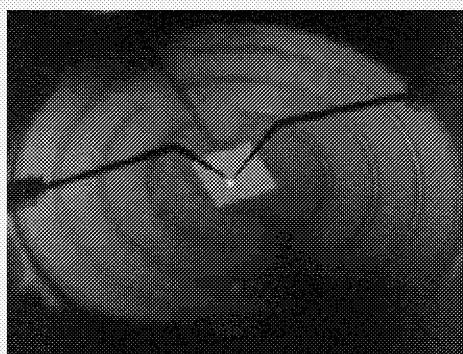
Hi-g SiC  
ACCELEROMETER



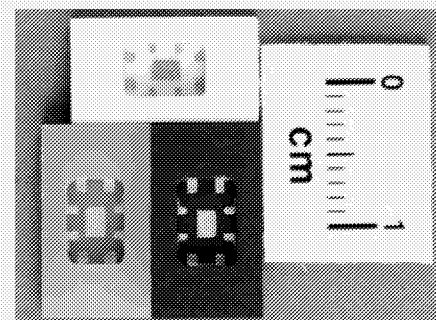
600°C  
PRESSURE SENSOR



MICROENGINE



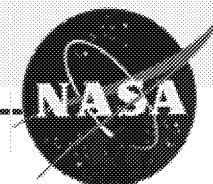
MICROELECTRONICS



HIGH TEMP PACKAGING

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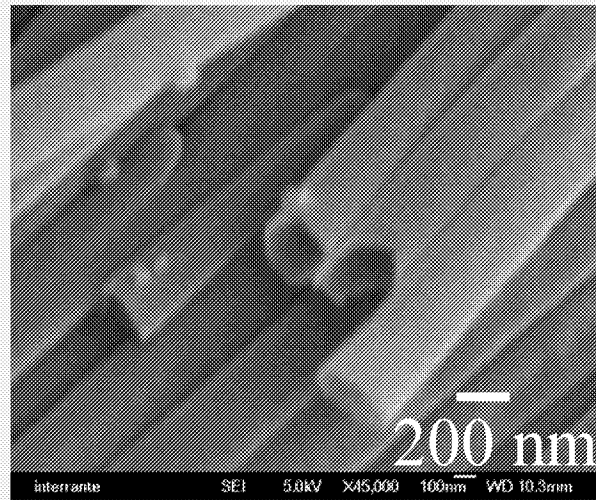
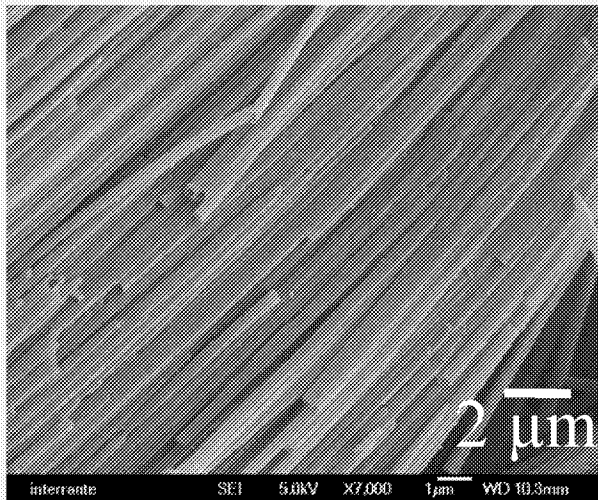
# High Temperature Nanotechnology

Determine chemical routes to SiC Nanotubes (SiCNTs) for advanced electronic and structural applications

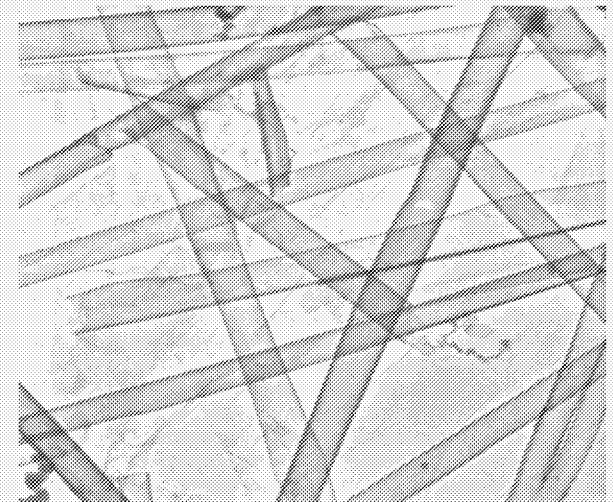
SiCNTs ( $d \sim 200$  nm) prepared at  $1000$  °C

- via CVD-template method.
- Nanotubes in high yield.
- Uniform Nanocrystalline tube-walls.
- Method easily scaled-up.

SEM

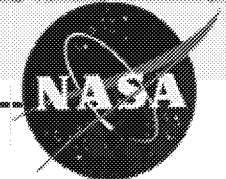


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# **Optical Instrumentation Technology Branch**

## **Scope of Work**

### **Advanced Optical Diagnostics for Ground Tests**

AeroSpace-propulsion facility instrumentation development.

Fluid T, P, V,  $\rho$ , chemical species, sprays, shocks.

Surface T, P, strain, defects.

### **Optical Flight Sensors and Systems**

AeroSpace-propulsion flight sensors and systems.

T, P, V, chemical species, shock waves, strain.

Light sources, connectors, actuators.

### **Electro-Optic circuitry**

Space-qualified electronics

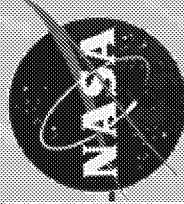
Vibration, radiation, EMI, imaging systems.

Ground systems

Mobile sensor platforms.

Real-time image processing.

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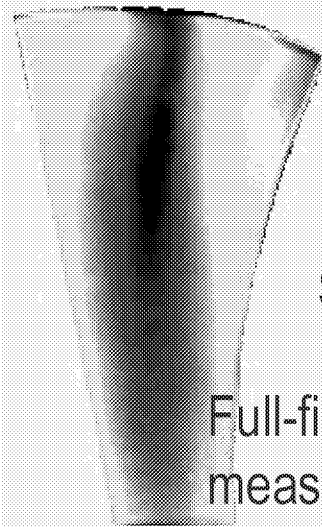
at Lewis Field



# Advanced Optical Diagnostics for Ground Tests

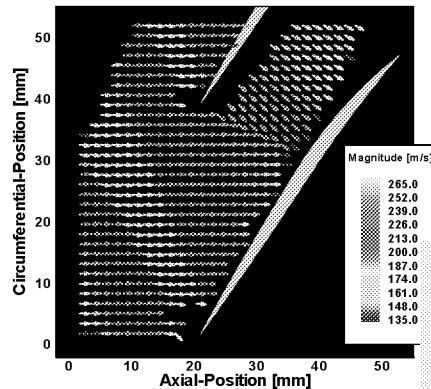
## Electronic Holography

Neural Net processing for real-time damage detection



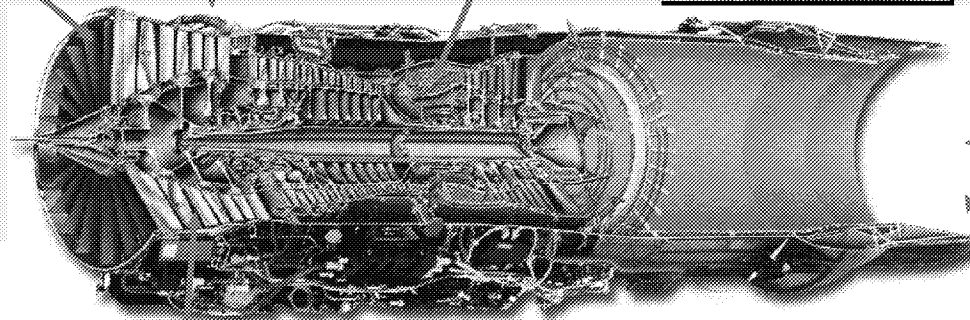
## Pressure Sensitive Paint

Full-field measurements on rotating parts



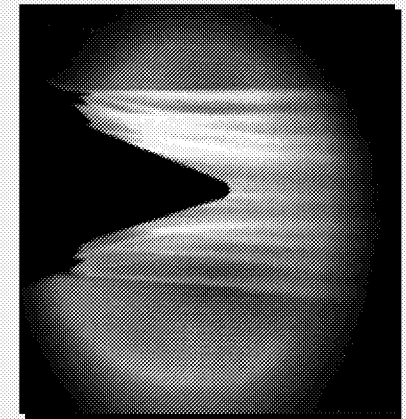
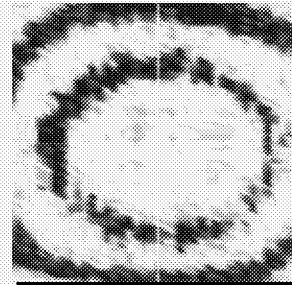
## Particle Imaging Velocimetry

Instantaneous and time-averaged planar velocity in confined spaces



## Planar Laser Induced Fluorescence

Fuel spray and species distributions



## Focused Schlieren Imaging

nozzle mixing

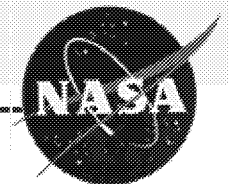
## Rayleigh Scattering

Density, temperature, & velocity



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# Micro-Optical Components for Flight Sensors

Fiber optic Bragg gratings detect strain (T, P)

Interferometric spectrometer enables dynamic data readout.

Sensors embedded into PMC plates, surviving up to 300C.

Waveguide fluorescence sensor

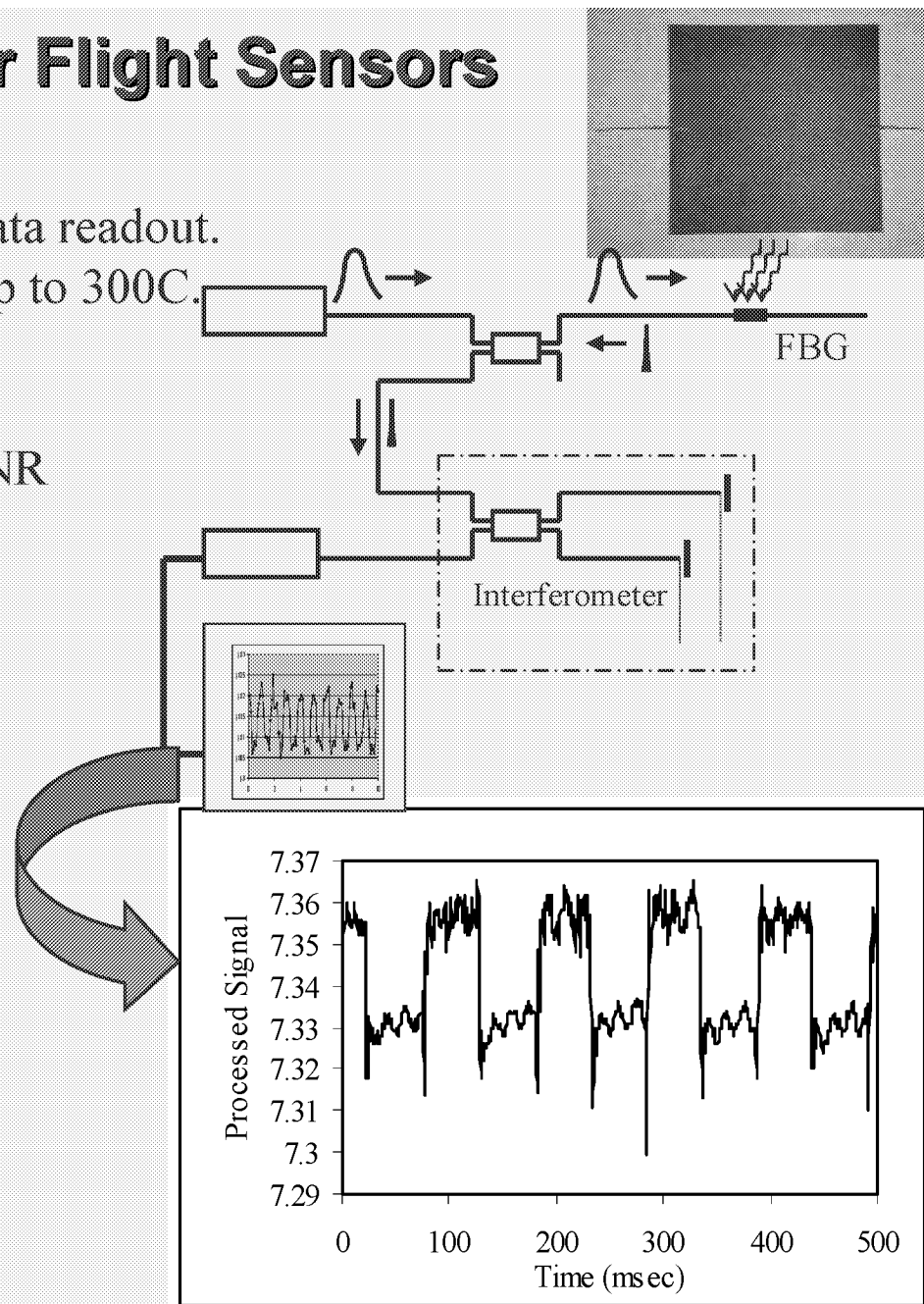
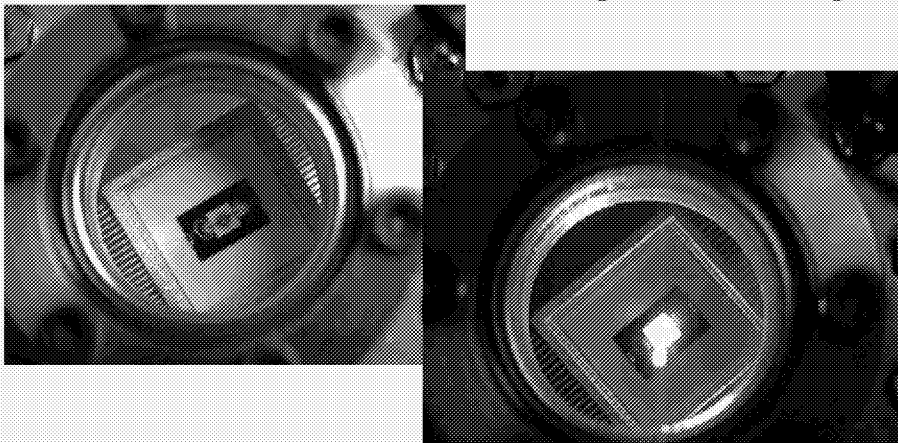
Surface plasmon cross coupling for increased SNR

“Lightbulb-on-a-chip” blackbody radiation

Compact, true white light source

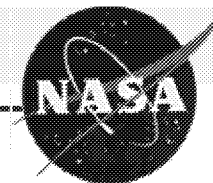
Optical actuation

Muscle wire, thermal leverage, surface gratings



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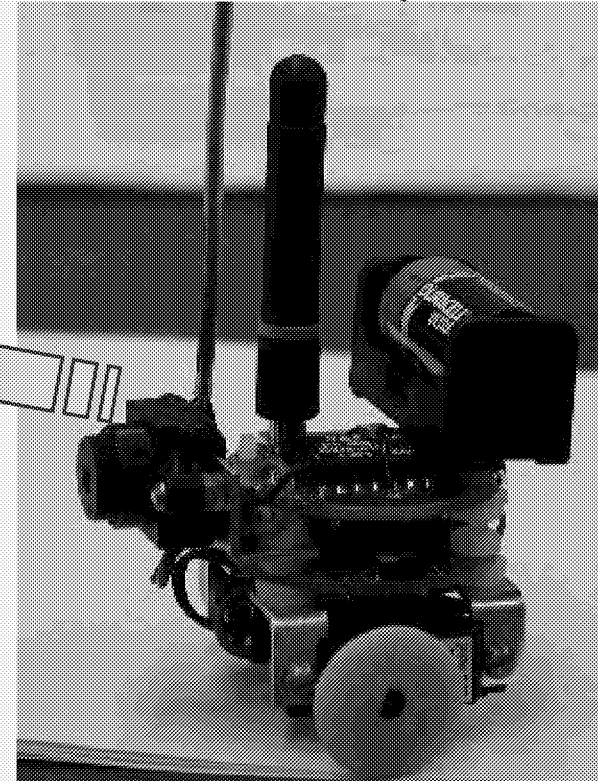
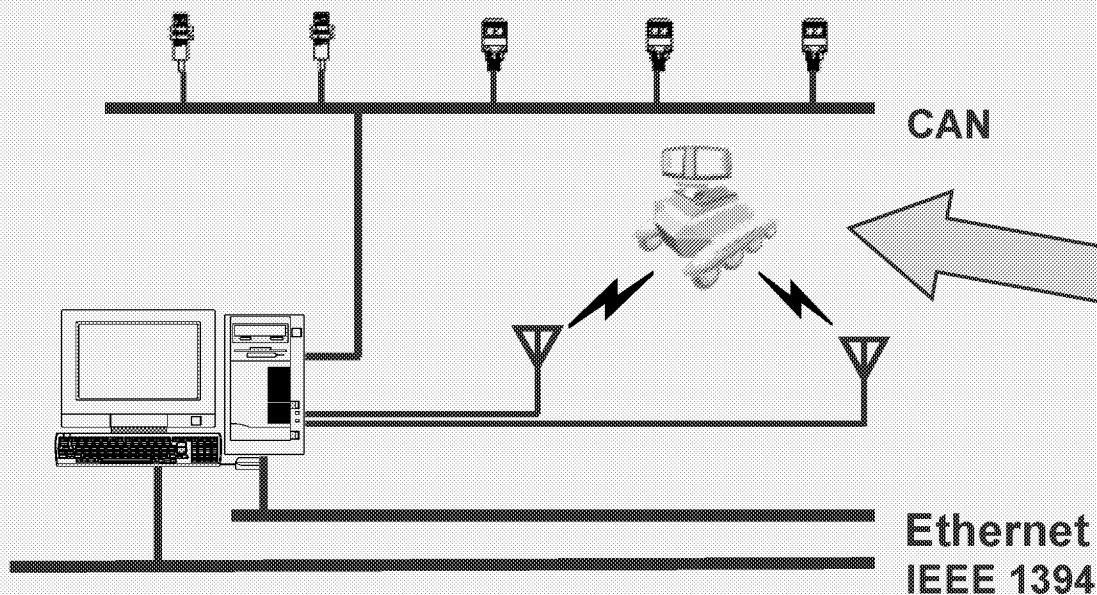
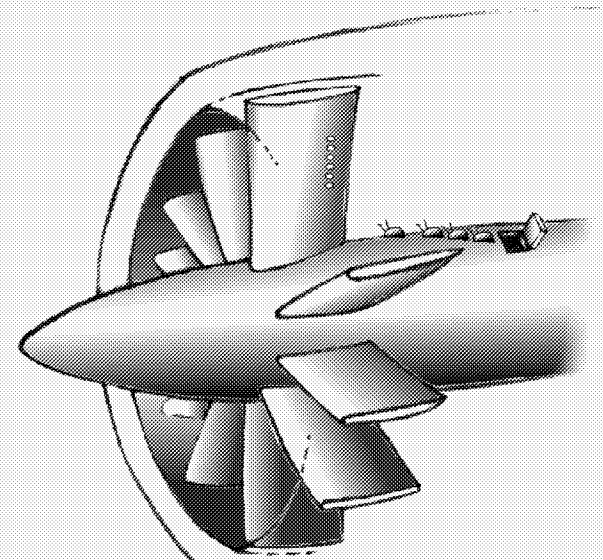


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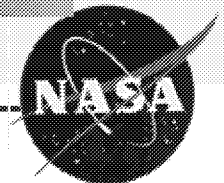
# Mobile Sensor Platforms

Mobile delivery systems and networked sensor communications for aerospace engine inspections, planetary exploration, and space experiments.



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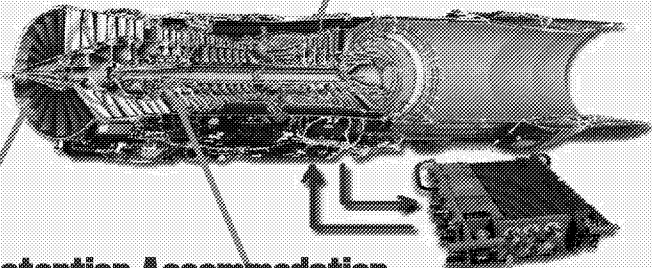


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# Controls and Dynamics Technology Branch

## Scope of Work

### Propulsion Controls



#### Inlet Distortion Accommodation

- Online Fan / Compressor Stability Margin Management
- Active Inlet Control

#### Active Flow Control

- High Bandwidth Actuation & Control Logic
- Stall Precursor Identification
- Microactuation

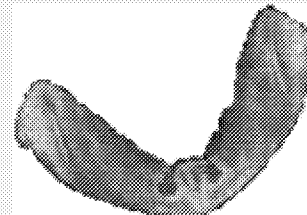
#### Active Combustion Control

- Emission Minimization
- Control of Thermo-acoustic Instability

#### Advanced Control Logic

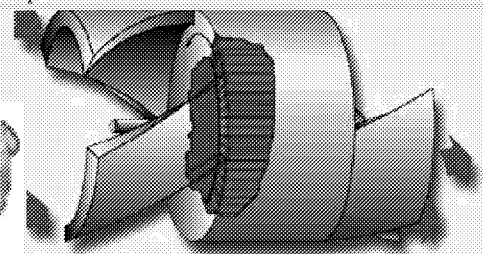
- Robust Multivariable Control Logic
- Fault Diagnostics & Accommodation
- Life Extending Control

### Dynamic Modeling



#### Nanotechnology

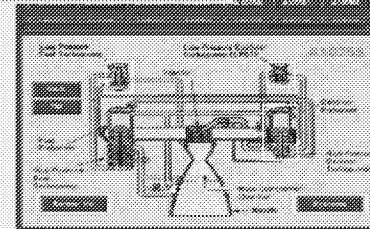
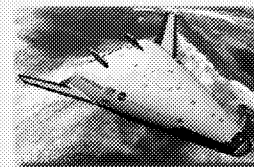
- Nanotube Actuators



#### Advanced Propulsion Concepts

- Wave Rotors
- Pulsejets
- High-speed Systems

### Health Management

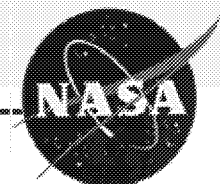


#### Propulsion Systems

- Prognostics & Diagnostics
- Data Mining & Data Fusion
- Sensor Validation

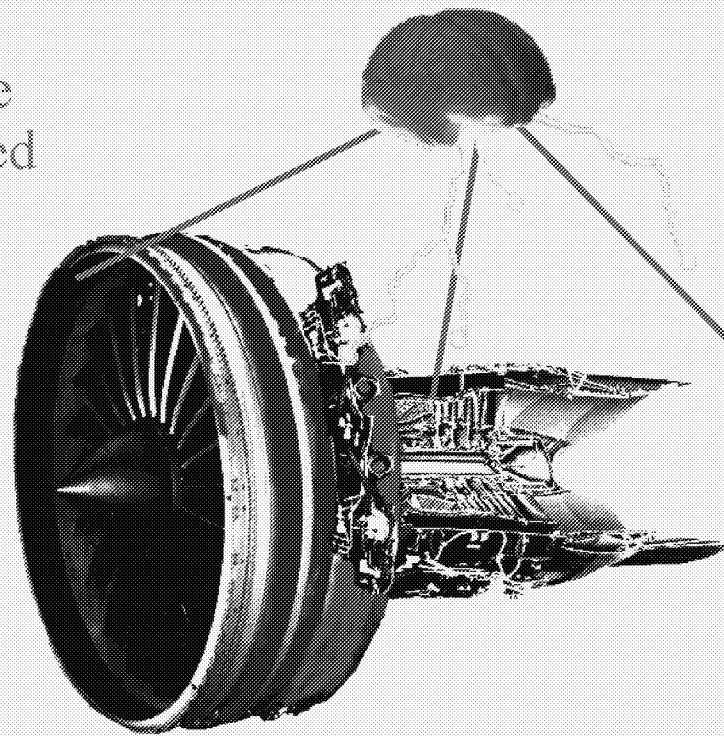
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Active Control  
for enhanced performance  
and reliability, and reduced  
emissions

- active control of  
combustor, compressor,  
vibration etc.
- MEMS based control  
applications



Advanced Health  
Management for self  
diagnostic and prognostic  
propulsion system

- Life usage monitoring and  
prediction
- Data fusion from multiple  
sensors and model based  
information

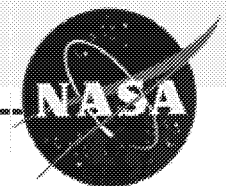
Distributed, Fault-Tolerant Engine Control for  
enhanced reliability, reduced weight and  
optimal performance with system deterioration

- Smart sensors and actuators
- Robust, adaptive control

**Multifold increase in propulsion system affordability,  
reliability, performance, capability and Safety**

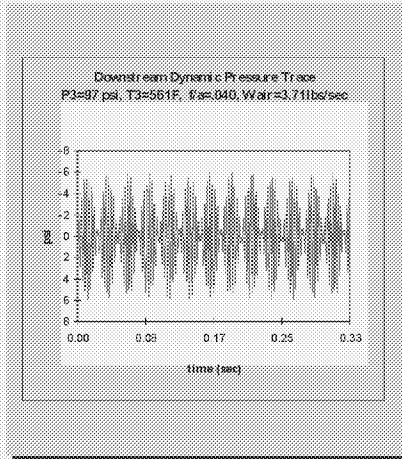
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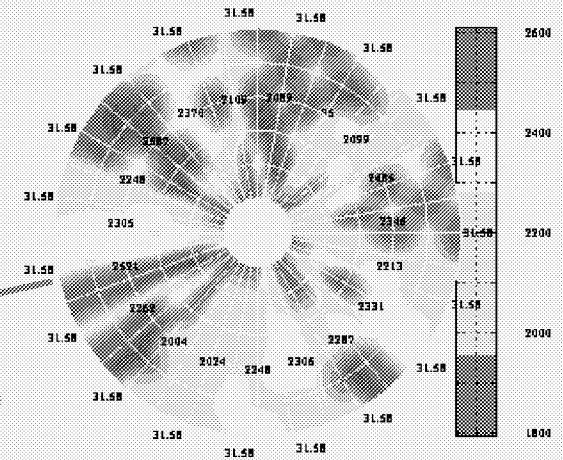
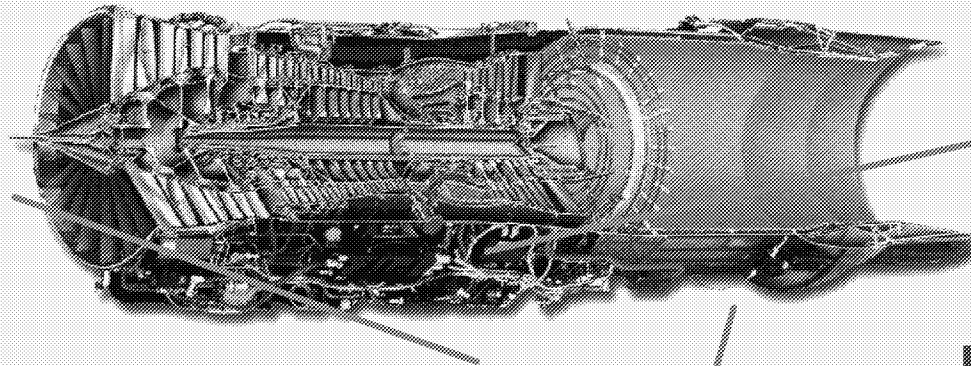
# Active Combustion Controls



## Combustion Instability Control

**objective:** actively suppress thermo-acoustic driven pressure oscillations

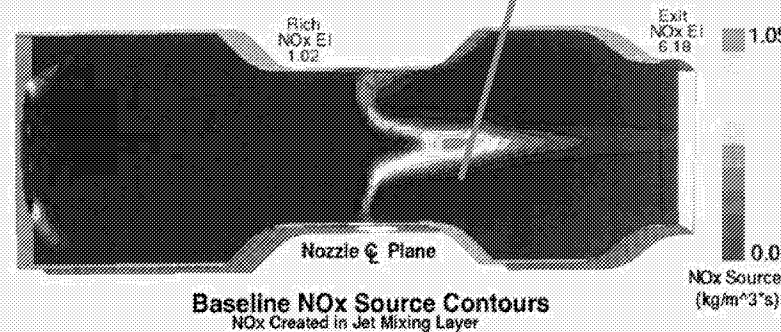
**participants:** P&W, UTRC, NASA (5530, 5830)



## Pattern Factor Control

**objective:** actively reduce combustor pattern factor

**participants:** AST, Allied Signal, NASA (5530, 5510)



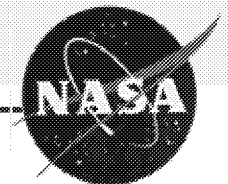
## Emission Minimizing Control

**objective:** actively reduce NOx production

**participants:** HSR, P&W, NASA (5530, 5520)

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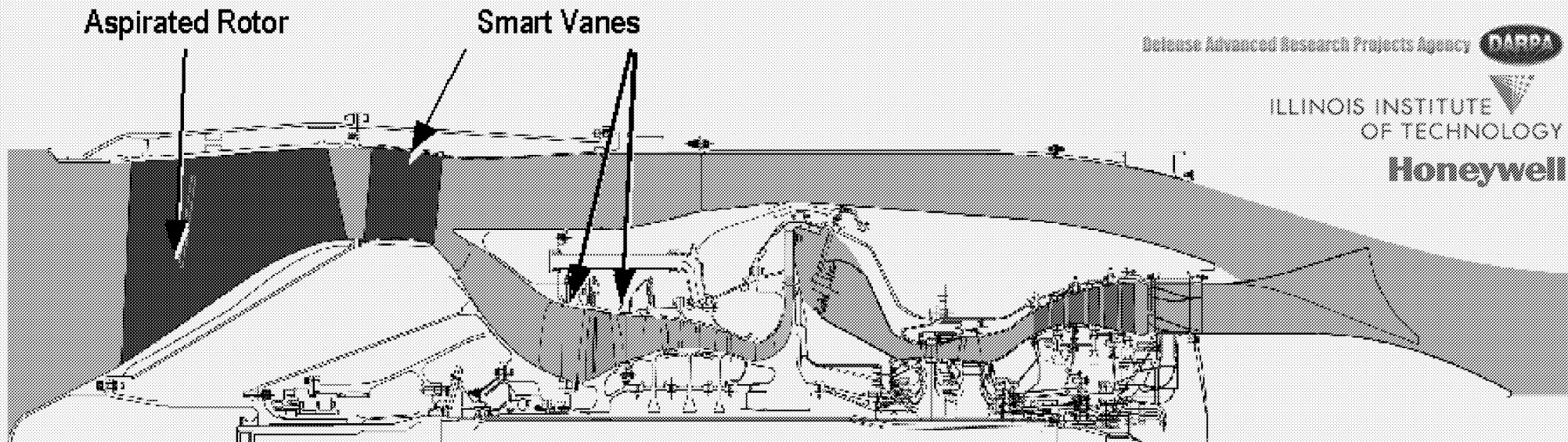


# Smart Vanes for UCAV Engines

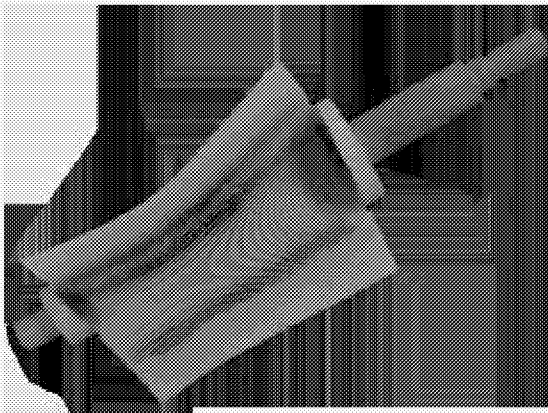
Defense Advanced Research Projects Agency **DARPA**

ILLINOIS INSTITUTE  
OF TECHNOLOGY

**Honeywell**

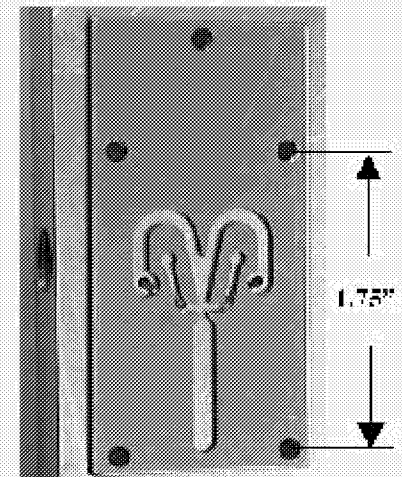


Smart Vane



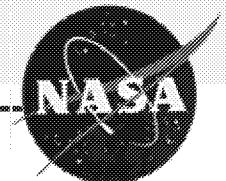
- Active Flow Control Applied to Stator Vanes
- Enables Higher Loading and Exit-Flow Vectoring Using Adaptive Closed-Loop Control System
- Enable Performance Enhancement, Reduced Costs and Reduced Weight of Gas-Turbine Engine Compression System
- Coupled with Aspirated Rotors for Increased System-Level Benefits

Fluidic Actuator



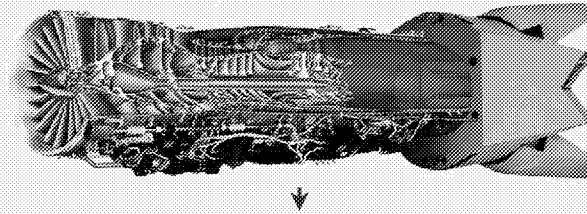
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# Data Fusion for Prognostics and Health Management



## Gas Path Measurements

- Temperatures
- Pressures
- Speeds
- Fuel Flow
- Actuator Positions

## Model & Tracking Filter

- Component Health Estimates

Maintenance,  
Overhaul &  
Operating History

## Mechanical Measurements

- Vibration
- Oil Pressure
- Oil Temperature
- Oil Quantity
- Fuel Pressure

## PHM Architecture Functionality

- Signal Processing
- Data Validation
- Feature Extraction
- Data Fusion
- Automated Decision Processing

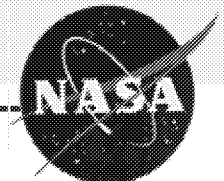
## Advanced Diagnostic & Prognostic Instrumentation

- Electrostatic Inlet Debris Monitor
- Engine Distress Monitor
- Eddy Current Blade Sensor
- Capacitance Tip Clearance Sensor
- Oil Condition Monitor

Maintenance and Inspection  
Advisories, Operating  
Advisories

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# Vision and Focus

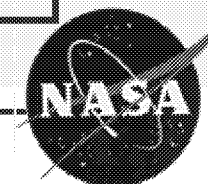
***The Vision -- Lead the Innovation and Application of Harsh Environment Microsystems for NASA and Industry***

***The Focus – SiC for Harsh Environments characterized by***

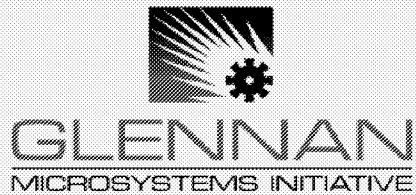
High Temperature (Sensors and Electronics)	-55C to 600C	Engines, Aircraft, Process Control, Environment Monitoring, Test and Measurement
Chemical Reactivity	Combustion species	Engines, Chemical Plants, Well Logging, Fuel Cells, Power Generation
High Loading and Vibration	>300,000G	Munitions, Test and Measurement
BioCompatibility	In vivo	Implantable Devices

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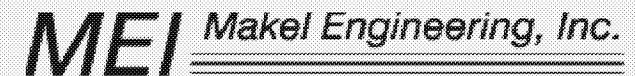
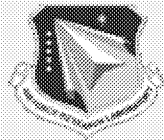
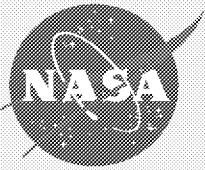
at Lewis Field



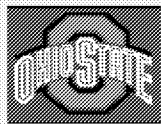




# Partners



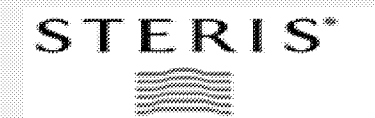
Research 2000



BMT

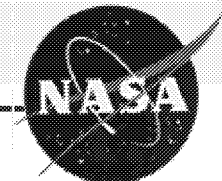


Cleveland Tomorrow



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# (5 year) Objectives

- **Four product platforms**
  - a high temperature pressure sensor
  - a multi-species chemical sensor
  - an in-vivo, catheter based drug delivery system
  - MUSiC, a multi-user SiC processing facility
- **Strategic partnerships** between GMI members.
- **The world's first and only SiC-Based MEMS manufacturing infrastructure** - based in Ohio
- **One new product** - developed from the product platforms
- **Three new companies built on GMI technology**
  - One Ohio-based company underway – FiberLead, Inc.